ADBA NATIONAL CONFERENCE
8 DEC 2022
LONDON
ONE GREAT GEORGE STREET
WESTMINSTER

Energy futures – what needs to happen to unleash the power of biogas

The Biomethane Ladder – putting forward the best use cases for biomethane

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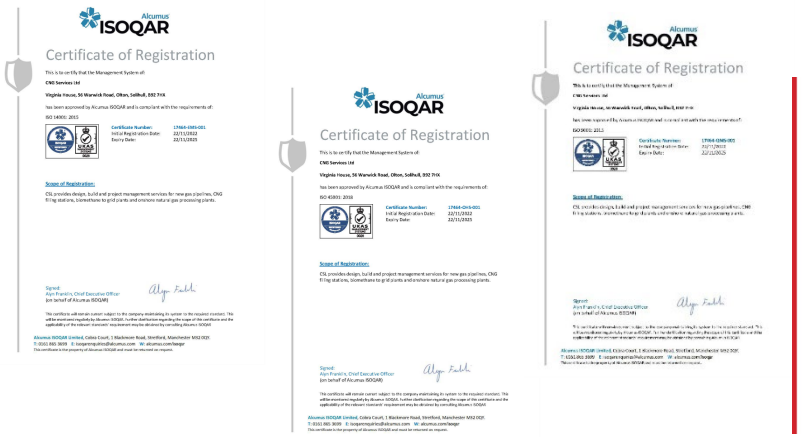
CNG Services Ltd

- CNG Services Limited (CSL) provides consultancy, design and build services to the biomethane industry, all focused on reducing Greenhouse Gas (GHG) emissions
- In the past 10 years our efforts have produced a material impact with an estimated 20 year project life reduction in CO_2 emissions of 17,500,000 tonnes through:
  - Biomethane injection into the gas grid
  - Running trucks on Bio-CNG
  - Acting as developer and design and build contractor for the Highlands CNG Project
- Working on a number of Biomethane, H_2 and CCUS innovation projects including:
  - Biomethane from manure with CCS
  - Biomethane direct into the NTS
  - Green H2 into the NTS and Hydrogen Business Model Projects
  - Reverse Compression to Create Capacity for Biomethane Injection
- CSL is an ISO 9001, 14001 and 45001 approved company and has also achieved Achilles certification. CSL is GIRS accredited for design and project management and has been certified as a competent design organisation for high pressure UK onshore natural gas works by DNVGL



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Before we get to the Ladder, a few suggestion as to what best practice might involve by 2030

1. Direct solar/wind/batteries to provide electricity for Biomethane Projects

- A typical AD is a semi-industrial site something between a farm and a factory
- It can be used to become a hub for multi-renewables with direct wire solar, wind (now its back) and batteries
- Being a source of 'electricity demand' is valuable
    - Heat Pumps for heating the digesters, liquid Bio-CO2 and Bio-CNG plants provide additional sources of electricity demand
- By 2030 ish, most ADs can be expected to have local solar, batteries and wind to secure 50% of their electricity from their own renewables, balance from the grid
- As batteries and solar fall in price the 50% can become 60% etc
- In addition, curtailed electricity from wind/solar will be available to bought at zero price (at times) and stored or used to make Green H2 (see next slide)

Onshore wind rules to be relaxed after Tory revolt

1 hour ago

GETTY IMAGES

The government has pledged to relax restrictions on building onshore wind farms in England after a threatened rebellion from Conservative MPs.

2. AD sites will be ideal places to make Green H2 – land, electricity grid connection, on site solar/wind/batteries

- No more staff required and probably no planning issues. AD sites are all connected to the electricity grid
- Green H2 may be able to react with Bio-CO2 to make more renewable methane or it may have local uses for industry or transport
- The point is all the ingredients to make Green H2 will be on site (catch rainwater from the digester roof and you are sorted)

Item	New Biomethane	Hydrogen	Comments
Key Plant	AD + Upgrader + GEU + compressors	Electrolyser + 30 bar H2 Storage vessels	Bought in from expert suppliers
Site works	Civils, electricity and gas grid connections, welded pipework	Civils, electricity grid (and maybe gas grid) connections, welded pipework	Similar skills
Feedstock	Agricultural/food industry waste with some crop (solar)	Solar/wind with batteries to improve load factor & elec grid to bring renewable elec	Zero carbon or GHG negative
Safety/Regulation	HSC/COMAH/DSEAR/PSR	HSC/COMAH/DSEAR/PSR	Same
Energy Product	Renewable CH4 and Bio-CO2 Compressed or liquid	Renewable H2 Compressed or liquid	Similar gases Inject into gas grid, use locally or move my road (compressed/liquid)
Nature of the gas	Heavy, relatively hard to ignite	Light and leaky	There are important differences
Use as Truck Fuel	Compressed or Liquid, local or remote via Grid or via truck deliveries	Compressed or Liquid, local or via truck deliveries	Use of gas grid for biomethane is main difference
Route to market for the Energy Product	Inject into the gas grid, use on site for trucks or take off site in 250 bar compressed biomethane trailers	Direct to I&C customer, use on site for trucks, inject into gas grid or take off site in 500 bar H2 trailers	Similar
Long term financial case	Cost to emit 1 tonne of CO2	Cost to emit 1 tonne of CO2	Similar
Security of supply impact	Every 1 kWh of biomethane saves 1 kWh of natural gas imports to Europe	Every 1 kWh of H2 saves 1 kWh of natural gas imports to Europe	Similar

3. For the Dunkelflaute, we will need to turn on gas engines for <5% load factor. AD sites are ideal places for them as they will (mostly) be on the gas grid

Dunkelflaute 'dark doldrums' or 'dark wind lull' is a term used to describe a period of time in which little to no energy can be generated with the use of wind and solar power

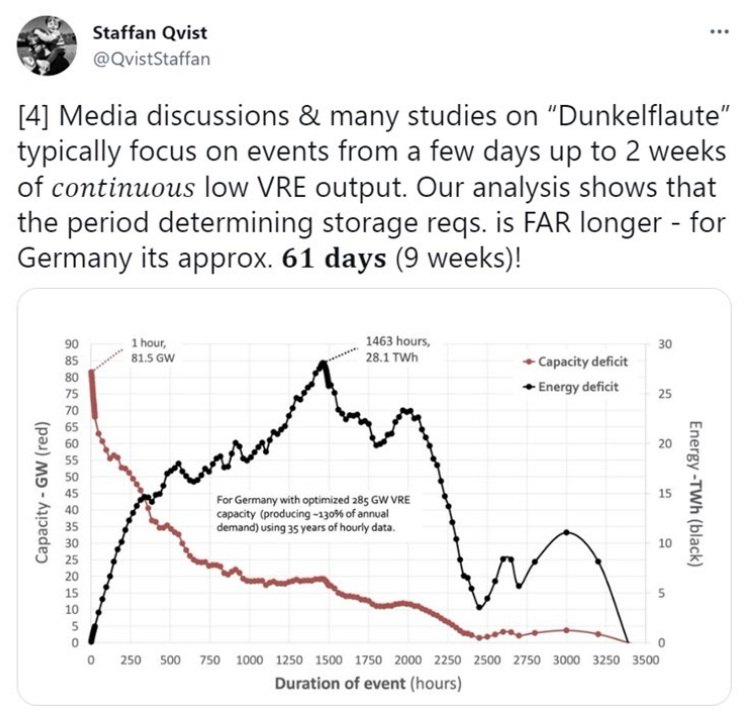
For UK post 2035 here are 2 main options for Dunkelflaute periods

1. **Use of H2**
    - Blue/Green H2 production plant
    - H2 storage (salt cavities)
    - H2 pipelines
    - H2 generation plant

2. **Fossil Gas with CCUS**
    - Fossil gas generation plant
    - Waste CO2 captured and sent to CCUS facilities eg HyNet/Teesside/Humber/Northern Lights

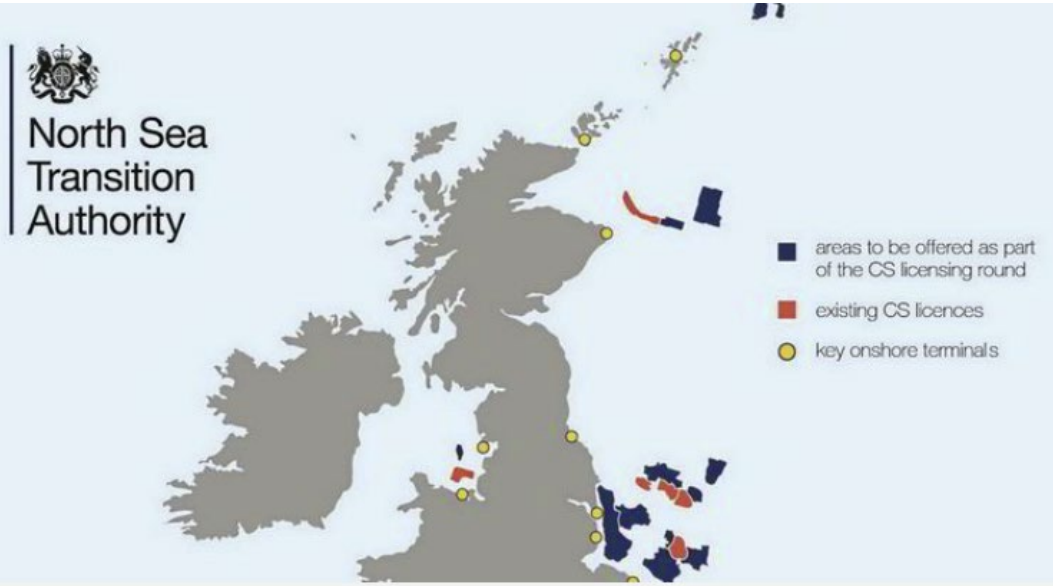
- But prior to 2035 its likely that the fall back option is **unabated gas engines** that can include ones on AD sites
- The Load Factor of all back up options – H2, gas with CCUS and gas engines will be <5% and falling by 2035
- The H2 and CCUS options will be very expensive on a cost per tonne of CO2 basis because of such a low load factor

There may be 10 years of <5 day a year Dunkelflaute and then a year with a longer one like below….tricky



4. Bio-CO2 is Valuable

- When we have talked before at Green Gas Day, it had a price of £50/tonne, today it is more like £200/tonne given the end of fertilizer manufacture in UK (though prices today may be several times higher?)
- We are not involved in new biomethane projects that aren't capturing and selling Liquid Bio-CO2. Why would you vent something so valuable? Indicative numbers below



Hydrogen

117. Hynet Hydrogen Pipeline
118. INOVYN Hydrogen Storage (Hynet Cluster, NW)
119. East Coast Cluster Hydrogen Pipeline
120. Aldbrough Hydrogen Storage (East Coast Cluster, Humber)
121. Hydrogen Electrolyser Capacity Deployment

Carbon Capture and Storage (CCUS)

122. Hynet Cluster – CCUS cluster in the North West
123. East Coast Cluster – CCUS cluster in Teesside and Humber

Parameter	Value	Unit
Biogas and AD Data		
Biogas Composition (%CH4)	60%	
Biogas Production Rate (60% CH4, 40% CO2)	1,000	Nm3/h
Biogas Production Rate	1,055	Sm3/h
AD Operation	100%	
Upgrader availability	97%	
AD Annual Production Hours	8,760	hours
Annual Biogas Production	9,241,319	Sm3/annum
Annual Biomethane Production	50,318,065	kWh/annum
CO2 Production		
Description	**Value**	**Unit**
Biogas Composition	40%	CO_2 (vol)
CO2 Capture Efficiency	90%	-
Potential CO2 Production	380	Sm^3/h
CO2 Recovery Plant Availability (Relative to BUU)	97%	-
CO2 Recovery Plant Operating Hours	8,497	h/annum
Annual CO2 Production (Mass)	6,103,217	kg/annum
Annual CO2 Production	6,103	tonnes/annum
Liquid CO2 Value - sold at the AD plant (indicative)	£150	/tonne
Annual CO2 Income	**£915,483**	/annum

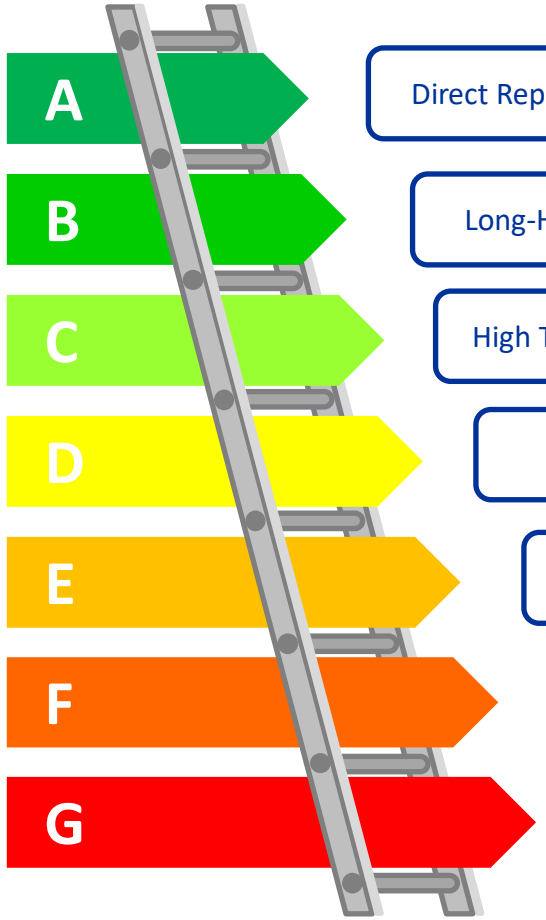
Now the Ladder

(with 2 bonus slides)

Biomethane Ladder (Dec 22)

And it is assumed that all the Bio-CO2 from the AD plant is captured, liquefied and used as per the Bio-CO2 ladder

Good options



- A: Direct Replacement of Fossil Methane in Manufacturing Processes; Shipping (liquid); Rocket Fuel (Liquid)
- B: Long-Haul HGVs; Energy (Gas) Storage
- C: High Temperature Industrial Heating
- D: Medium-Haul HGVs; Back-up Generation for Dunkelflaute (Low load factor)
- E: Local Delivery vehicles; Utilisation in CHPs for Electricity Production with waste heat used
- F: Gas central heating; Cars; Intercity Trains and Buses
- G: Hydrogen Production (with no CO2 capture)

The ladder changes over time as circumstances change and represents an indicative hybrid of economics, feasibility and GHG outcome

Poor options

Based on 'The Clean Hydrogen Ladder' by Liebrich Associates

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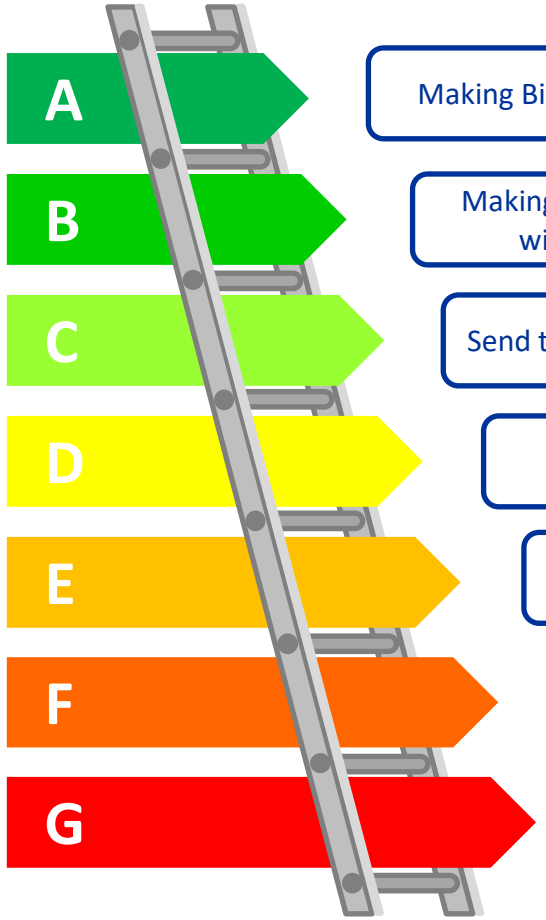
Bio-CO2 Ladder (Dec 22)

And it is assumed that all the Biomethane goes into the gas grid and is used as per the Biomethane Ladder

Good options



- Making Bio-Methanol with Green H2
- Making Liquid Bio-methane SPACEX
- Making Bio-kerosene aeroplane Fuel
- Making Bio-Methanol with Blue H2
- Bio-methane using Bio-CO2 from the AD plant
- CCS by adding to Concrete
- Send to offshore CCS
- CO2 as fire suppressant
- CO2 as inert in industry
- Growing vegetables
- Smothering chickens
- Making beer
- Dry ice
- Release to atmosphere

The UK biomethane market is very well placed in Europe because of 3 critical factors:

- BEIS Support for CCUS (Hynet and East Coast Clusters)
- Vast offshore wind resource in Irish and North Sea
- Salt strata at these clusters which allows both H2 (and Bio-CO2) to be stored which is critical for premium top rung products

Poor options

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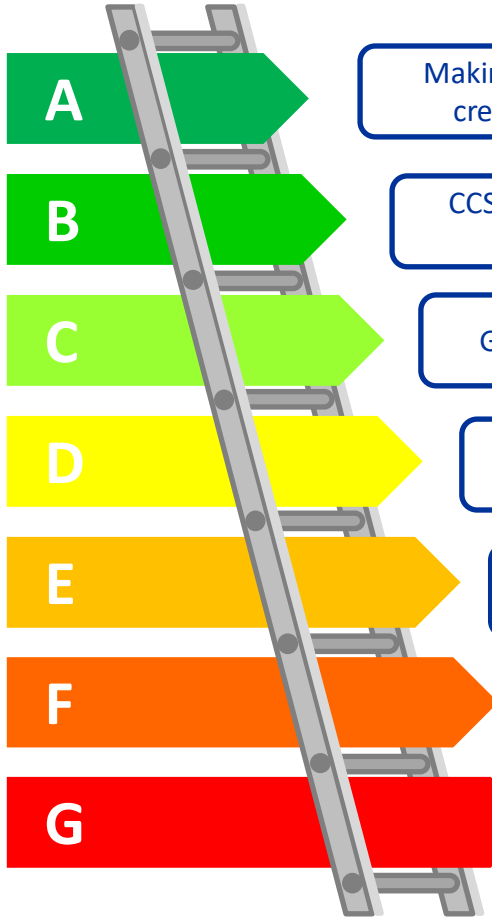
Bio-CO2 Ladder

X-mas Special

Good options



- A: Making ice cream; Making Beer bubbles; Champagne bubbles; Sterilising Glenmorangie bottles; Growing brussels sprouts to make biomethane
- B: CCS in permafrost at North pole; Chimney unblocking CO2 lance; Making vanilla milk shake; Growing Cocoa beans to make chocolate
- C: Growing Xmas trees; Make greener grass to feed reindeers
- D: Artificial snow/snowball manufacture
- E: Sending turkeys to meet their maker; Mince pie fluffing agent
- F: Soda stream
- G: Party dry ice

Have a top rung Christmas everybody

Poor options

Based on 'The Clean Hydrogen Ladder' by Liebrich Associates

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Biomethane and Bio-CO2 Conclusions

1. **Don't burn any biogas** (new projects)
2. **Don't vent any Bio-CO2**, liquefy it and sell it or send to CCUS (new and existing projects)
    - Bio-CO2 will be a valuable product to make bio-methanol and similar things
3. **Build direct wire** solar/wind/batteries (new and existing projects) to supply the base load electricity demand
4. **Plan for making Green H2** for multiple uses (new and existing)
5. **Plan for Dunkelflaute back-up gas engines** on the AD site (new and existing)
6. **Don't burn any diesel** - run trucks and farm tractors on Bio-CNG (new and existing)
7. **Use local direct wire and grid renewable electricity and heat pumps** to heat the digesters (new)

One final thing, to keep the GB Biomethane industry moving forward, we must **sort capacity for biomethane projects as well as use the NTS**